

Supplementary Information

Tree height and hydraulic traits shape growth responses across droughts in a temperate broadleaf forest

Ian R. McGregor, Ryan Helcoski, Norbert Kunert, Alan J. Tepley, Erika B. Gonzalez-Akre, Valentine Herrmann, Joseph Zailaa, Atticus E.L. Stovall, Norman A. Bourg, William J. McShea, Neil Pederson, Lawren Sack, Kristina J. Anderson-Teixeira

List of Tables

1	Table S1: Species-specific bark thickness regression equations	3
2	Table S2: Species-specific height regression equations	4
3	Table S3: Monthly Palmer Drought Severity Index (PDSI), and its rank among all years between 1950 and 2009 (driest=1), for focal droughts.	5
4	Table S4. Individual tests of species traits as drivers of drought resistance, where Rt is used as the response variable.	6
5	Table S5. Individual tests of species traits as drivers of drought resistance, where Rt_{ARIMA} is used as the response variable.	7
6	Table S6. Summary of top full models for each drought instance, where Rt is used as the response variable.	8
7	Table S7. Summary of top models for each drought instance, where Rt_{ARIMA} is used as the response variable.	9

List of Figures

1	Figure S1: Map of ForestGEO plot showing TWI and location of cored trees	11
2	Figure S2: Time series of Palmer Drought Severity Index (PDSI) for the 2.5 years prior to each focal drought	12
3	Figure S3: Height (from reconstructed DBH) by canopy position across the three focal droughts and in the year of measurement (2018)	13
4	Figure S4: PLACEHOLDER	14
5	Figure S5: Comparison of Rt and Rt_{ARIMA} results, with residuals, for each drought scenario	14
6	Figure S6: PLACEHOLDER	15

While there were several R-packages we used for a specific purpose in our methods, numerous packages were immensely helpful for this research behind the scenes. As in all of science, this study is a representation of the work done by both the authors of this paper as well as countless others. While acknowledging everyone is impossible, we want to at least give thanks to those who made this work possible.

R-packages not already cited in the main manuscript include the following, listed alphabetically by corresponding package name:

(???, Wickham, 2019; Allaire *et al.*, 2020; Gagolewski *et al.*, 2020; R Core Team, 2020; Xie, 2020)

Table S1: Species-specific bark thickness regression equations

Species	Equations	R^2
<i>Carya cordiformis</i>	$\ln[B] = -1.56 + 0.416 * \ln[DBH]$	0.226
<i>Carya glabra</i>	$\ln[B] = -0.393 + 0.268 * \ln[DBH]$	0.040
<i>Carya ovalis</i>	$\ln[B] = -2.18 + 0.651 * \ln[DBH]$	0.389
<i>Carya tomentosa</i>	$\ln[B] = -0.477 + 0.301 * \ln[DBH]$	0.297
<i>Fagus grandifolia</i>	$\ln[B] = 1 * \ln[DBH]$	
<i>Fraxinus americana</i>	$\ln[B] = 0.418 + 0.268 * \ln[DBH]$	0.256
<i>Juglans nigra</i>	$\ln[B] = 0.346 + 0.279 * \ln[DBH]$	0.246
<i>Liriodendron tulipifera</i>	$\ln[B] = -1.14 + 0.463 * \ln[DBH]$	0.545
<i>Quercus alba</i>	$\ln[B] = -2.09 + 0.637 * \ln[DBH]$	0.603
<i>Quercus prinus</i>	$\ln[B] = -1.31 + 0.528 * \ln[DBH]$	0.577
<i>Quercus rubra</i>	$\ln[B] = -0.593 + 0.292 * \ln[DBH]$	0.087

Table S2: Species-specific height regression equations

Species	Equations	X.R.2.
<i>Carya cordiformis</i>	$\ln[H] = 0.332+0.808*\ln[DBH]$	0.874
<i>Carya glabra</i>	$\ln[H] = 0.685+0.691*\ln[DBH]$	0.841
<i>Carya ovalis</i>	$\ln[H] = 0.533+0.741*\ln[DBH]$	0.924
<i>Carya tomentosa</i>	$\ln[H] = 0.726+0.713*\ln[DBH]$	0.897
<i>Fagus grandifolia</i>	$\ln[H] = 0.708+0.662*\ln[DBH]$	0.857
<i>Liriodendron tulipifera</i>	$\ln[H] = 1.33+0.52*\ln[DBH]$	0.771
<i>Quercus alba</i>	$\ln[H] = 0.74+0.645*\ln[DBH]$	0.719
<i>Quercus prinus</i>	$\ln[H] = 0.41+0.757*\ln[DBH]$	0.886
<i>Quercus rubra</i>	$\ln[H] = 1.00+0.574*\ln[DBH]$	0.755
all	$\ln[H] = 0.839+0.642*\ln[DBH]$	0.857

Table S3: Monthly Palmer Drought Severity Index (PDSI), and its rank among all years between 1950 and 2009 (driest=1), for focal droughts.

year	month	PDSI	rank
1966	May	-2.98	2
	June	-3.40	2
	July	-4.08	2
	August	-4.82	1
1977	May	-2.96	3
	June	-3.28	3
	July	-3.61	3
	August	-3.68	3
1999	May	-3.63	1
	June	-4.21	1
	July	-4.53	1
	August	-4.64	2

Table S4. Individual tests of species traits as drivers of drought resistance, where Rt is used as the response variable.

variable	category	all droughts		1966		1977		1999	
		$\Delta AICc$	coefficients	$\Delta AICc$	coefficients	$\Delta AICc$	coefficients	$\Delta AICc$	coefficients
xylem porosity	R	-4.53	0.0680	2.42**	0.190	1.7*	-0.151	3.97**	0.1580
	D/SR		0.0000		0.000		0.000		0.0000
<i>PLA</i>		-2.89	-0.0140	8.98**	-0.025	-0.26	-0.010	-0.91	-0.0070
<i>LMA</i>		-12.76	0.0001	-1.9	0.001	-1.64	-0.002	-2.06	0.0001
π_{ulp}		-2.23	-0.1620	-1.77	-0.093	1.27*	-0.251	-0.52	-0.1530
<i>WD</i>		-3.96	-0.0380	-1.17	-0.220	-1.5	-0.151	0.43	0.2640

Variable abbreviations are as in Table 2. $\Delta AICc$ is the AICc of a model excluding the trait minus that of the model including it.

* $\Delta AICc > 1$: variable meets $\Delta AICc$ criterion for inclusion in full model

** $\Delta AICc > 2$: variable is considered significant as an individual predictor (and meets $\Delta AICc$ criterion for inclusion in full model)

Table S5. Individual tests of species traits as drivers of drought resistance, where Rt_{ARIMA} is used as the response variable.

variable	category	all droughts		1966		1977		1999	
		$\Delta AICc$	coefficients	$\Delta AICc$	coefficients	$\Delta AICc$	coefficients	$\Delta AICc$	coefficients
xylem porosity	R	-5.28	0.0430	0.82	0.1500	2.79**	-0.178	2.47**	0.158
	D/SR		0.0000		0.0000		0.000		0.000
<i>PLA</i>		-5.13	-0.0120	10.32**	-0.0240	-0.91	-0.009	-1.68	-0.005
<i>LMA</i>		-12.70	0.0003	-2.04	0.0005	-0.53	-0.003	-1.9	0.001
π_{tlp}		-2.56	-0.1530	-1.91	-0.0640	-0.29	-0.201	-0.16	-0.190
<i>WD</i>		-3.93	-0.0380	-0.2	-0.2970	-1.68	-0.134	0.72	0.313

Variable abbreviations are as in Table 2. $\Delta AICc$ is the AICc of a model excluding the trait minus that of the model including it.

** $\Delta AICc > 2$: variable considered significant as an individual predictor

Table S6. Summary of top full models for each drought instance, where Rt is used as the response variable.

drought	$\Delta AICc$	R^2	Intercept	$\ln[H]$	$\ln[TWI]$	$\ln[H] * \ln[TWI]$	crown position				PLA	π_{tlp}
							D	C	I	S		
all	0.000	0.12	1.131	-0.057	-0.086	-	-	-	-	-	-0.012	-0.113
	0.583	0.11	1.423	-0.055	-0.086	-	-	-	-	-	-0.013	-
	0.702	0.12	1.046	-0.09	-0.079	-	-0.034	0	-0.038	-0.052	-0.012	-0.101
	0.726	0.12	1.537	-0.202	-0.326	0.082	-	-	-	-	-0.012	-0.114
	0.783	0.11	1.299	-0.09	-0.079	-	-0.034	0	-0.039	-0.055	-0.014	-
	1.237	0.12	1.482	-0.246	-0.337	0.088	-0.035	0	-0.038	-0.053	-0.012	-0.101
	1.347	0.11	1.733	-0.245	-0.335	0.088	-0.036	0	-0.039	-0.056	-0.014	-
	1.352	0.11	1.826	-0.198	-0.324	0.081	-	-	-	-	-0.013	-
1966	0.000	0.25	1.622	-0.135	-	-	-	-	-	-	-0.025	-
	1.987	0.26	1.680	-0.155	-	-	-0.039	0	0.015	-0.062	-0.025	-
1977	0.000	0.23	0.460	-	-0.134	-	-0.068	0	-0.025	0.047	-	-0.253
	0.036	0.22	0.503	-	-0.144	-	-	-	-	-	-	-0.24
	0.944	0.21	1.069	-	-0.144	-	-	-	-	-	-	-
	1.024	0.22	0.568	-0.03	-0.139	-	-	-	-	-	-	-0.246
	1.116	0.25	0.646	-	-0.132	-	-0.069	0	-0.025	0.046	-0.007	-0.217
	1.180	0.24	0.684	-	-0.142	-	-	-	-	-	-0.007	-0.204
	1.230	0.22	1.059	-	-0.134	-	-0.069	0	-0.027	0.041	-	-
	1.303	0.22	1.211	-	-0.141	-	-	-	-	-	-0.01	-
	1.508	0.23	1.206	-	-0.132	-	-0.07	0	-0.027	0.041	-0.01	-
	1.934	0.23	0.501	-0.013	-0.133	-	-0.067	0	-0.029	0.037	-	-0.252
1999	0.000	0.20	1.265	-0.058	-0.092	-	0.001	0	-0.076	-0.09	-	-
	0.095	0.19	1.086	-	-0.099	-	-0.006	0	-0.055	-0.048	-	-
	0.236	0.18	1.061	-	-0.102	-	-	-	-	-	-	-
	0.259	0.19	0.659	-	-0.101	-	-	-	-	-	-	-0.169
	0.519	0.21	0.907	-0.058	-0.091	-	0.002	0	-0.075	-0.087	-	-0.151
	0.600	0.21	0.729	-	-0.098	-	-0.005	0	-0.053	-0.046	-	-0.15
	0.901	0.21	1.367	-0.059	-0.09	-	0	0	-0.077	-0.091	-0.007	-
	0.999	0.20	1.186	-	-0.097	-	-0.006	0	-0.055	-0.049	-0.007	-
	1.190	0.19	1.157	-	-0.1	-	-	-	-	-	-0.007	-
	1.750	0.21	0.783	-	-0.1	-	-	-	-	-	-0.005	-0.145
	1.805	0.19	1.127	-0.066	-	-	-0.002	0	-0.081	-0.096	-	-
	1.886	0.20	1.509	-0.14	-0.229	0.046	0	0	-0.077	-0.091	-	-
	1.922	0.23	1.048	-0.059	-0.09	-	0.001	0	-0.076	-0.088	-0.005	-0.123

Models are ranked by AICc. Shown are all models whose AICc value falls within 2.0 ($\Delta AICc < 1$) of the best model (bold).

Table S7. Summary of top models for each drought instance, where Rt_{ARIMA} is used as the response variable.

drought	dAICc	R^2	Intercept	$\ln[H]$	$\ln[TWI]$	$\ln[H] * \ln[TWI]$	crown position				PLA	π_{tlp}
							D	C	I	S		
all	0.000	0.09	1.125	-0.307	-0.506	0.14	-	-	-	-	-0.012	-
	0.425	0.10	0.879	-0.31	-0.508	0.14	-	-	-	-	-0.011	-0.096
	1.208	0.09	0.424	-0.06	-0.1	-	-	-	-	-	-0.012	-
	1.695	0.10	0.178	-0.061	-0.1	-	-	-	-	-	-0.011	-0.095
1966	0.000	0.23	1.66	-0.154	-	-	-	-	-	-	-0.024	-
	1.393	0.23	1.735	-0.152	-0.047	-	-	-	-	-	-0.024	-
	1.457	0.23	1.859	-0.152	-	-	-	-	-	-	-0.025	0.078
1977	0.000	0.16	1.13	-	-0.18	-	-	-	-	-	-	-
	0.424	0.16	2.453	-0.461	-0.896	0.25	-	-	-	-	-	-
	0.688	0.17	0.72	-	-0.179	-	-	-	-	-	-	-0.173
	0.922	0.17	2.04	-0.466	-0.898	0.251	-	-	-	-	-	-0.18
	0.927	0.17	1.248	-	-0.177	-	-	-	-	-	-0.008	-
	1.082	0.16	1.108	-	-0.172	-	-0.06	0	-0.003	0.072	-	-
	1.269	0.17	0.634	-	-0.171	-	-0.059	0	-0.001	0.077	-	-0.199
	1.322	0.17	2.569	-0.461	-0.893	0.25	-	-	-	-	-0.008	-
	1.470	0.17	2.205	-0.383	-0.87	0.24	-0.07	0	0.014	0.098	-	-
	1.709	0.15	1.183	-0.02	-0.177	-	-	-	-	-	-	-
	1.752	0.18	1.731	-0.384	-0.87	0.241	-0.069	0	0.016	0.103	-	-0.201
	1.932	0.17	1.229	-	-0.169	-	-0.061	0	-0.003	0.072	-0.009	-
1999	0.000	0.20	0.563	-	-0.076	-	-	-	-	-	-	-0.2
	0.064	0.19	0.421	-	-	-	-	-	-	-	-	-0.202
	0.127	0.18	1.036	-	-0.077	-	-	-	-	-	-	-
	0.256	0.18	-	-	-	-	-	-	-	-	-	-
	1.777	0.20	0.529	0.016	-0.078	-	-	-	-	-	-	-0.195
	1.797	0.20	1.101	-	-0.076	-	-	-	-	-	-0.004	-
	1.815	0.18	0.986	0.018	-0.079	-	-	-	-	-	-	-
	1.838	0.20	0.972	-	-	-	-	-	-	-	-0.005	-
	1.933	0.19	0.391	0.012	-	-	-	-	-	-	-	-0.199
	1.979	0.21	0.612	-	-0.075	-	-	-	-	-	-0.002	-0.19
	1.999	0.21	0.482	-	-	-	-	-	-	-	-0.002	-0.19

Models are ranked by AICc. Shown are all models whose AICc value falls within 2.0 ($\Delta AICc < 1$) of the best model (bold).

Allaire J, Xie Y, McPherson J, Luraschi J, Ushey K, Atkins A, Wickham H, Cheng J, Chang W, Iannone R. **2020**. *Rmarkdown: Dynamic documents for r*.

Gagolewski M, Tartanus B, IBM, Unicode, Inc., Unicode, Inc. **2020**. *Stringi: Character string processing facilities*.

R Core Team. **2020**. *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Wickham H. **2019**. *Stringr: Simple, consistent wrappers for common string operations*.

Xie Y. **2020**. *Knitr: A general-purpose package for dynamic report generation in r*.

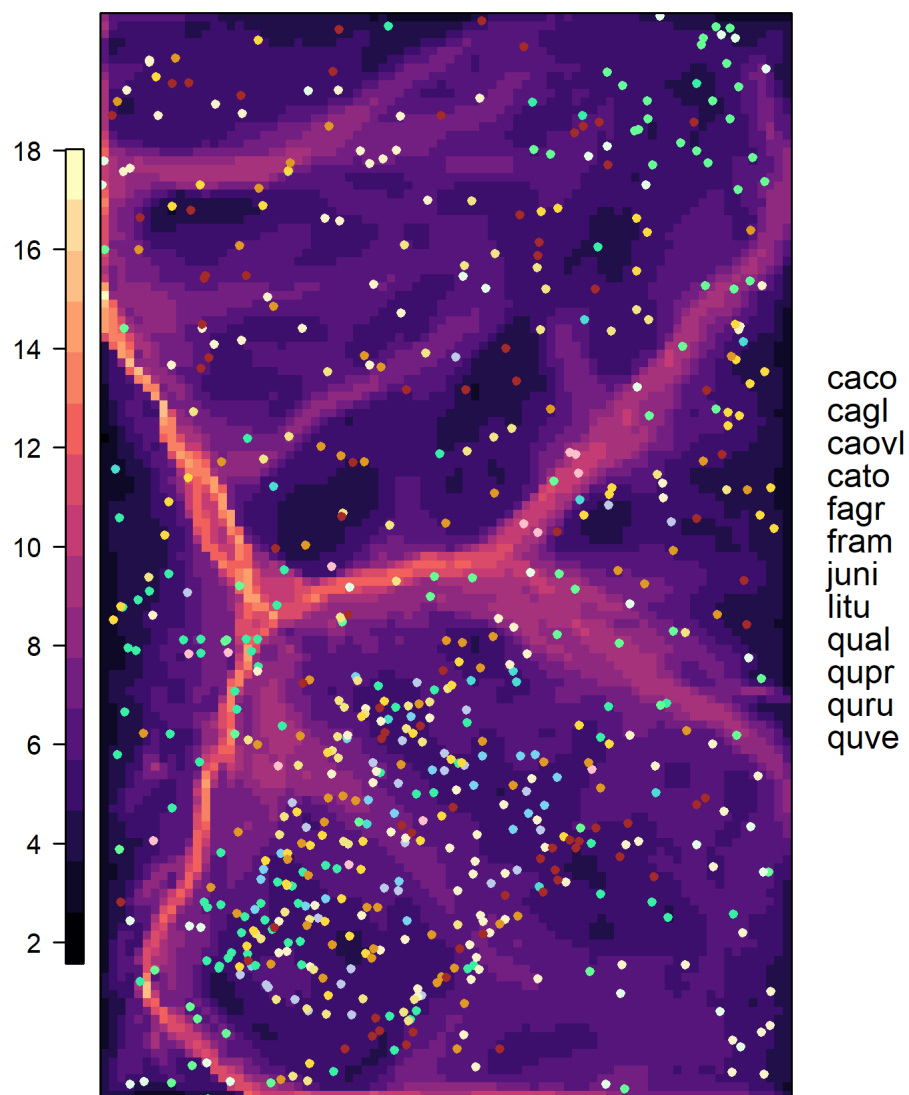


Figure S1: Map of ForestGEO plot showing TWI and location of cored trees

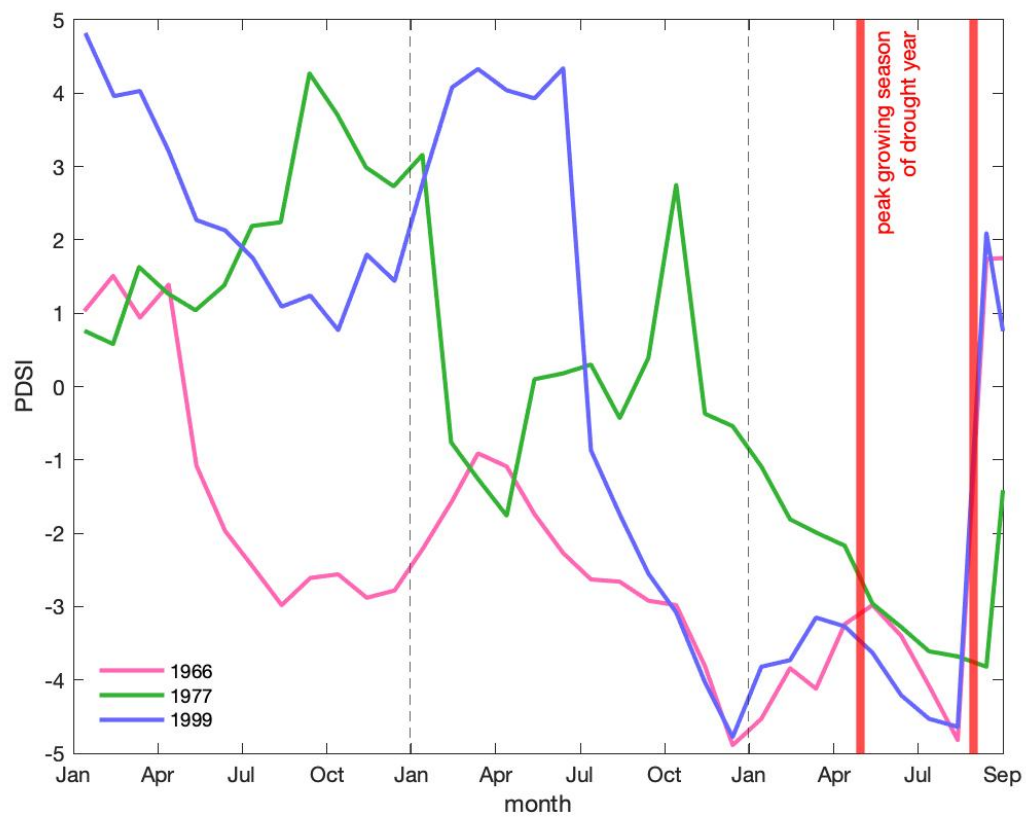


Figure S2: Time series of Palmer Drought Severity Index (PDSI) for the 2.5 years prior to each focal drought

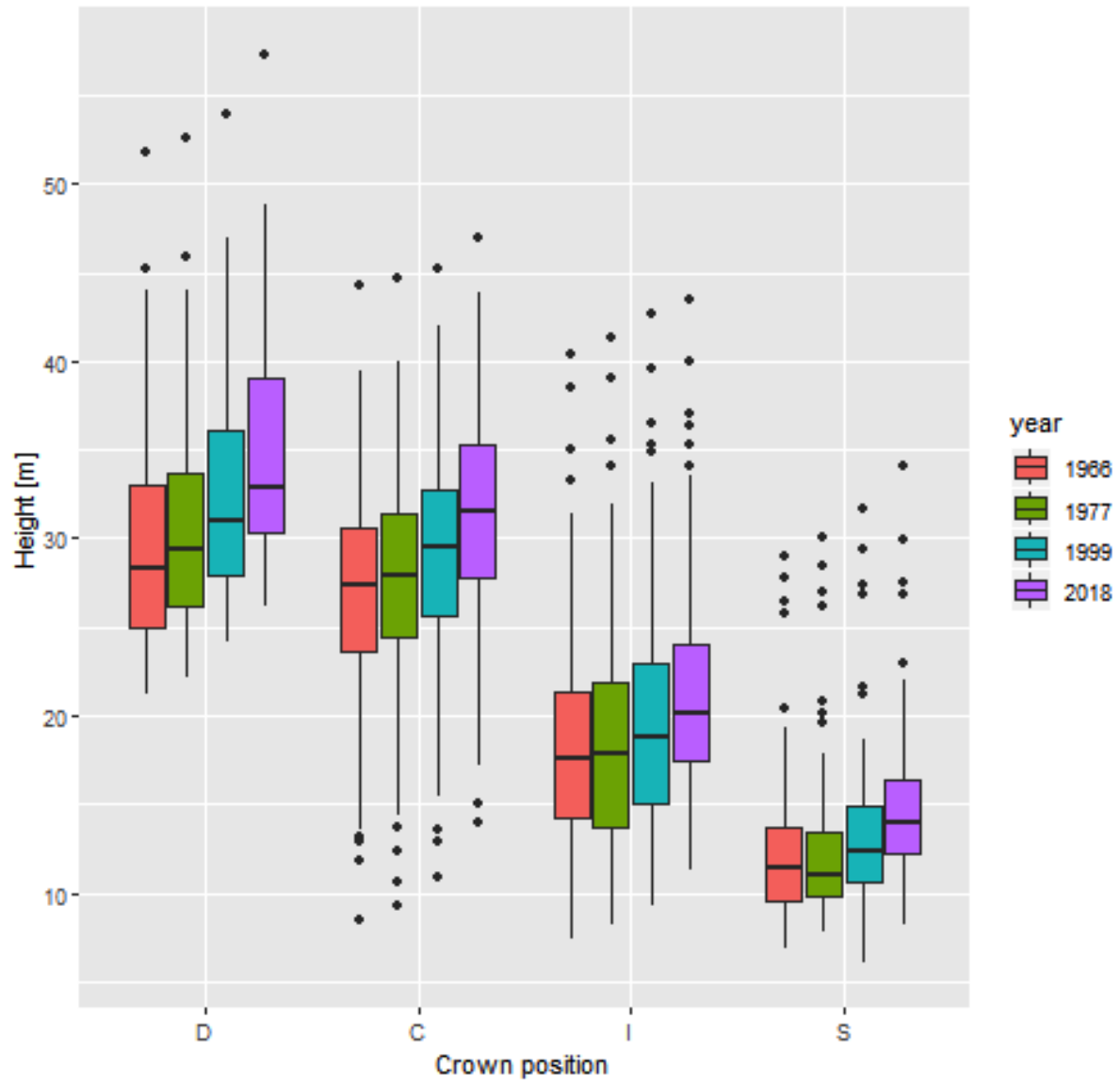


Figure S3: Height (from reconstructed DBH) by canopy position across the three focal droughts and in the year of measurement (2018)

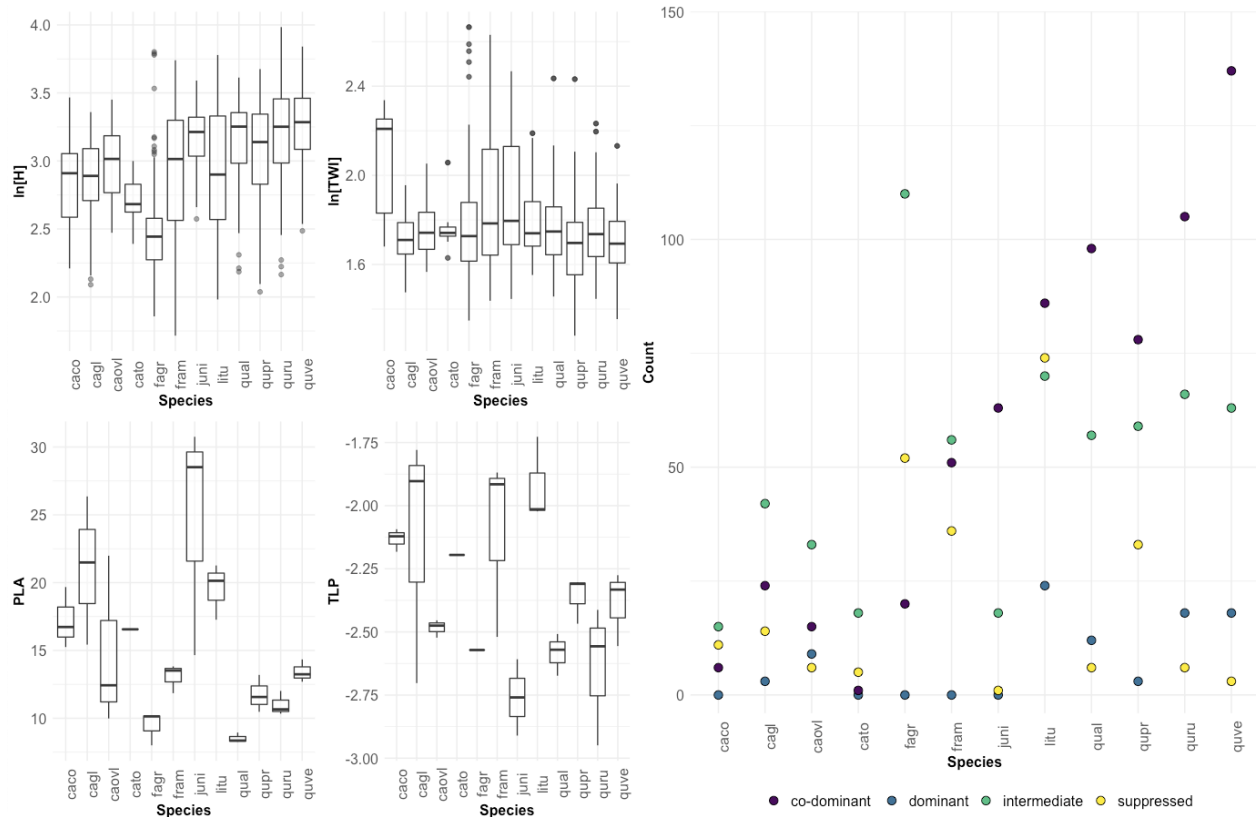


Figure S4: **PLACEHOLDER**

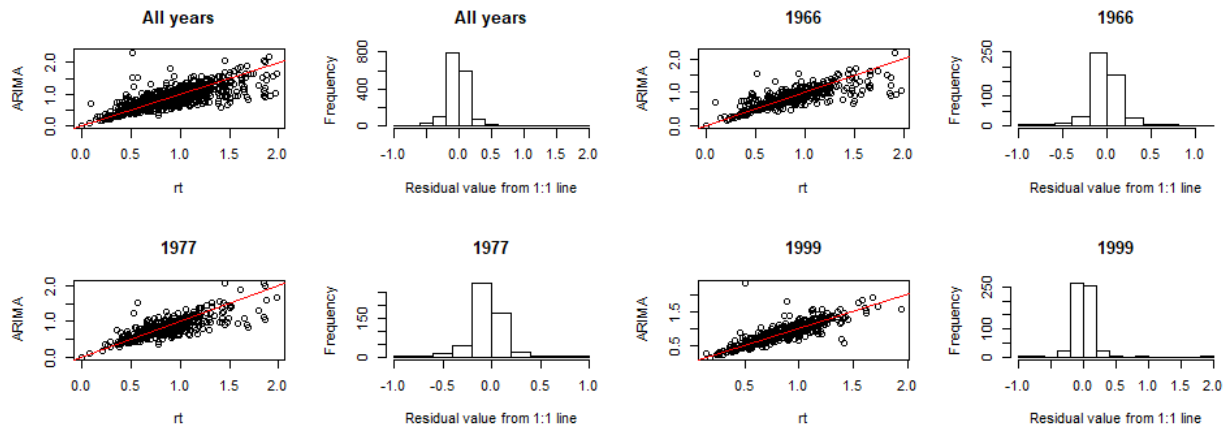


Figure S5: Comparison of R_t and $R_{t,ARIMA}$ results, with residuals, for each drought scenario

